Climate Change and its Impact on Biodiversity: Research requirements in Sarawak, Borneo

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Workshop on Climate Change and Biodiversity:
Mobilizing the Research Agenda

Universiti Kebangsaan Malaysia, Bangi
13-14 December 2010

Federal Legislation & Policy

1. Irrigation Areas Act 1953
2. Drainage Works Act 1954
3. Land Conservation Act 1960
4. Wildlife Protection Act 1972
5. Environmental Quality Act 1974
7. Forestry Act 1984
8. Fishery Act 1985
17. Third National Agricultural Policy 1998-2010
23. Green Technology Policy 2009
24. Government Transformational Programme Roadmap, 2010
Sarawak Legislation & Policy

1. Sarawak Land Code 1958
2. Natural Resource and Environmental Ordinance, Chapter 84, 1958
3. Forest Rules, 1962
4. Natural Resources and Environment Ordinance 1993 (Amended 2001)
5. Public Parks and Green Ordinance 1993
6. Sarawak Rivers Ordinance 1993
7. Water Ordinance 1994
8. Sarawak Forestry Corporation Ordinance, 1995
9. Forest Ordinance (Cap.126), Amendment 1996
10. Sarawak Biodiversity Centre Ordinance, 1997 (Cap. 24).
17. Veterinary Public Health Ordinance 1999
18. Local Authority (Cleanliness) By-Law 1999

Background

Global environment
- GHG 25% increase fossil fuel
- Global warming increase 0.2°C/decade
- Sea level increase 3.1 ± 0.7 mm/yr

Malaysia
- 15,500 species of higher plants (686 spp plants threatened)
- 746 birds (42 spp)
- 300 mammals (70 spp)
- 379 reptiles (21 spp)
- 198 amphibians (47 spp)
- 368 species of fish (49 spp)
- 19 spp molluscs
- Other inverts 207
- 1,141 species endangered (IUCN 2008)

Total forest area: 20,890,000 ha
% of land area: 63.6%

Primary forest cover: 3,820,000 ha
% of land area: 11.6%

Annual change in forest cover: -140,200 ha (2000-2005)
Annual deforestation rate: -0.7%

Oil palm cultivation in 2008: 4.48 mil. Ha
Palm oil (crude) production in 2008: 17.73 mil. T
Sarawak Background

- Population in 2006: 2,357,500.
- Area: 124,450 km² or 12 million ha
- Forest cover 5.9 million hectares (30%)
- 1.5 million ha peatland around Kuching, Kota Samarah, Sibu, Sri Aman, Mukah & Miri
  cleared for oil palm plantation
- Permanent Forest Estate, PFE: 6 million ha; timber production
- TPAs: 880,000 ha, 8% land area; 19 NPs, 5NRs & 4 WSs
- Stateland: 1.7 million ha, can be alienated

Forests in Malaysia: 19.4 million hectares (59.5% of the total land area); approximately 1.55 million hectares of swamp forests in Malaysia. Of this total, 0.31 million hectares or 19% are in Peninsular Malaysia and 1.12 million hectares or 73% in Sarawak. The peat swamp forest cover in Sarawak is about 0.88 million hectares

Table 2: Distribution and extent of major forest types in Malaysia, 2005 (Million hectares).

<table>
<thead>
<tr>
<th>Region</th>
<th>Land Area</th>
<th>Natural Forest</th>
<th></th>
<th></th>
<th>Plantation Forest</th>
<th>Total Forested Land</th>
<th>Percentage Total of Forested Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peninsular Malaysia</td>
<td>13.16</td>
<td>5.40</td>
<td>0.31</td>
<td>0.10</td>
<td>0.09</td>
<td>5.90</td>
<td>44.8</td>
</tr>
<tr>
<td>Sabah</td>
<td>7.37</td>
<td>3.83</td>
<td>0.12</td>
<td>0.34</td>
<td>0.11</td>
<td>4.40</td>
<td>59.7</td>
</tr>
<tr>
<td>Sarawak</td>
<td>12.30</td>
<td>7.92</td>
<td>1.12</td>
<td>0.14</td>
<td>0.06</td>
<td>9.24</td>
<td>75.1</td>
</tr>
<tr>
<td>Malaysia</td>
<td>32.83</td>
<td>17.15</td>
<td>1.55</td>
<td>0.58</td>
<td>0.26</td>
<td>19.54</td>
<td>59.5</td>
</tr>
</tbody>
</table>

Land Use Pattern

<table>
<thead>
<tr>
<th>Region</th>
<th>Oil palm (ha)</th>
<th>Peat Land (ha)</th>
<th>Oil palm on peat</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. Malaysia</td>
<td>2,503,682.02</td>
<td>716,944.00</td>
<td>207,458.01</td>
<td>8.29</td>
</tr>
<tr>
<td>Sabah</td>
<td>1,340,317.39</td>
<td>121,514.00</td>
<td>21,405.75</td>
<td>1.60</td>
</tr>
<tr>
<td>Sarawak</td>
<td>1,167,172.51</td>
<td>1,588,142.00</td>
<td>437,174.27</td>
<td>37.45</td>
</tr>
<tr>
<td>Total</td>
<td>5,011,171.92</td>
<td>2,426,600.00</td>
<td>666,038.03</td>
<td>13.29</td>
</tr>
</tbody>
</table>


Fauna have no equivalent list in Borneo?

<table>
<thead>
<tr>
<th>Bornean Fauna</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 mammalian spp as Bornean endemics</td>
<td>Wilson &amp; Reeder, 2005</td>
</tr>
<tr>
<td>622 spp birds</td>
<td>Davison, 1999</td>
</tr>
<tr>
<td>105 spp lizards, plus crocodiles and turtles; 166 spp snakes</td>
<td>Das &amp; Ghazally, 2001, 2002 D. Das, 2008</td>
</tr>
<tr>
<td>150 spp frogs</td>
<td>Inger &amp; Stuebing, 2005</td>
</tr>
<tr>
<td>~4500 spp macromoths</td>
<td>Holloway, 1985 – 2008</td>
</tr>
<tr>
<td>&gt;350 spp phasmids</td>
<td>Bragg, 2001</td>
</tr>
<tr>
<td>275 spp dragonflies</td>
<td>Orr, 2003</td>
</tr>
<tr>
<td>550 spp beetle, family Cerambycidae</td>
<td>~1000 ha plot in Kalimantan Timur; Fatawa &amp; Mori, 2000</td>
</tr>
<tr>
<td>394 spp fish, 149 spp Bornean endemic</td>
<td>Kottelat <em>et al</em>. 1993</td>
</tr>
<tr>
<td>249 spp in Sarawak &amp; Brunei</td>
<td>Kottelat &amp; Lim, 1995</td>
</tr>
<tr>
<td>A miniature fish, a tree frog, and a catfish are among 52 new species</td>
<td></td>
</tr>
</tbody>
</table>
Lesson from LGM-Holocene climate change

Rain forest contraction & expansion.

Pleistocene refugia & ancient Sunda River with moist forest
- Refugia and Sunda River network facilitate movement and genetic exchange
- Post LGM isolation resulting in allopatric speciation.
- Niah & Borneo extinction

Species: Borneo's elephants are indigenous to Borneo, have undergone independent evolution 300K yr since a Pleistocene colonisation and isolation (Fernando, 2003).

Lesson on LGM-Holocene climate change

Pleistocene refugia & ancient Sunda River with moist forest

Fig. 8 Majority rule consensus tree clustering 34 mtDNA haplotypes of H. sumatranus and their geographical distribution. Numbers at the forks indicate the percent of times the group consisting of the haplotypes located to the right of the fork occurred among the trees, out of 10,000 trees. The tree was rooted with haplotype 35.

ESU vs MU?
Chiropteran Case Studies in UNIMAS


1. MtDNA Cyt b, COI & nuclear amplified fragment length polymorphisms & cranial-dental morphology.
2. Supported species level clades with one unidentified Kerivoula species.
3. Intraspecific diversification events coincided with Pliocene and Pleistocene epochs.
4. Northeastern Sabah specimens had high genetic divergence indicating Pleistocene or Pliocene refugia in Borneo.

Fig. 2.—Bayesian phylogeny of left mitochondrion b (Cytb) sequences and right neighbor-joining phylogram of amplified fragment length polymorphisms (AFLP). Scores on the Cytb branches refer to bootstrap support values (1,000 iterations) from maximum likelihood (1st score), maximum parsimony (2nd score), minimum evolution (3rd score), and Bayesian posterior probabilities (4th score); − = no support value. Maximum parsimony (1st score) and Bayesian posterior probabilities (2nd score) are shown on the AFLP phylogram. Clades (A, B, C, D, E, F, G) and (H, I, J, K) are identified according to species identification. Some internal branches and similar haplotype support values were omitted from the figure. Species labeled by tissue number (TK, UNIMAS) and collecting region: swBO = southwestern Borneo, cBO = central Borneo, eBO = eastern Borneo, and PM = Peninsular Malaysia. Refer to "Materials and Methods" for suggested changes in voucher specimen numbers in Stahlman et al. (2004).


Fig. 3.—Chronogram of Southeast Asian Kerivoula studied here. Values at each node represent mean time to most recent common ancestor estimates from dating analyses performed in BEAST version 1.5. Gray bars represent the 95% highest posterior density intervals for the divergence estimates. Species: K. bat — K. hardwickii, K. inta — K. intermedia, K. luci — K. lucifugus (AB341969), K. lon — K. lentis, K. min — K. minuta, K. pap — K. papillosa, K. pel — K. pellicuda, K. cf. lon — K. cf. lentis (AB341970), and K. sp — potential undescribed species (see "Discussion"); TK 150001). Collecting regions: swBO = southwestern Borneo, cBO = central Borneo, eBO = eastern Borneo, and PM = Peninsular Malaysia. Geologic time: Plio = Pliocene and Ples = Pleistocene. Outgroup not shown.
**Phylogeography & Evolution**

- **77 inds of *P. lucasi*** - Miri (33); Kuching (33); Sri Aman (5) & Kelantan (5)
- **mtDNA Cytochrome b (cyt b) gene**
  - 1061 bp of cyt b - 77 sequences; 45 unique haplotypes; 6 shared haplotypes
- **Two haplogroups** - Haplogroup 1 (Kuching & Miri); Haplogroup 2 (Miri, Kuching, Sri Aman & Kelantan) (3.88%)
- **High** genetic divergence between haplotypes (4.9%).
- **High gene flow** (*Nm > 1.0*) between Kuching - Miri.
- **Two haplogroup - multiple colonisation during Pleistocene**
- Sharing haplotypes between Kuching & Miri - past geographical (migration) histories
- **Two putative species** was detected within Kuching & Miri populations.
  

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**Intraspecific Morphological Diversity**

- **70 adult** specimens of *P. lucasi*; Kuching – 38 (14 M & 24 F); Miri – 25 (16 M & 9 F) & Sri Aman – 7 (2 M & 5 F)
- **33 characters** (15 external & 18 skull)

**Result & Discussion**

- **Sexual dimorphism** - separate analyses
- Best loading character - D4MCL & BL for male; HF & IF for female
- *P. lucasi* from different populations - able to be distinguished accordingly
- **Bio-ecological factors**;
  - breeding,
  - foraging behaviour
  - resource availability
  - crowding effect
  - selective pressure
  - **climate change**

- Absence or minimum number of migrations have occurred between these populations.
- Thus, populations have adapted to their ecological environments.

Recommendations:
• 9 new distribution records - 7 Niah NP; 2 Wind Cave
• Niah NP- *H. ater*, *H. bicolor*, *H. cineraceus*, *C. robinsoni*, *R. trifoliatus*,
  *M. rozendaalii* & *K. hardwickii*;
• Wind Cave NR- *H. ridleyi* & *T. robustula*.
• **Limestone areas** - higher number of bats spp Niah NP and BLA - 44 and
  37 spp of bat.
• **Hotspot areas** - rich bat diversity in Sarawak.
• Bats in Borneo are threatened due to habitat loss, cave disturbance,
  ecotourism, climate change and hunting.
• The **proper management** of bats in these areas should be
  implemented by management authorities

1. Discovered two *Hampala bimuculata* in Borneo.
2. One in central and southern parts of Sarawak, *Hb* type A.
3. Second *Hb* in northern Sarawak and west coast of Sabah.
4. Sharing of *H. macrolepidota* in southern PM and southern Sarawak hypotypes showed of Pleistocene migration.

Contemporary climate change & biodiversity

- Human-induced cases
  - Land use conversion, deforestation, logging, habitat loss & degradation
  - Agricultural development – market economy
  - Settlement, urbanisation & infrastructural development - population increase.
  - Industrialisation, combustion, slash and burn
  - Uncontrolled consumptive use

- Natural phenomena activities
  - Climate itself
  - Tsunami
  - Volcano

Pleistocene-Holocene Extinction

<table>
<thead>
<tr>
<th>Sarawak</th>
<th>Malaysia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuon alpinus</td>
<td>Palaeoloxodon namadicus</td>
</tr>
<tr>
<td>C. familiaris ?</td>
<td>Elephantidae</td>
</tr>
<tr>
<td>Panthera tigris</td>
<td>Hexaprotodon sp.</td>
</tr>
<tr>
<td>Tapirus indicus</td>
<td>Duboisia santeng</td>
</tr>
<tr>
<td>Rhinoceros sondaicus</td>
<td></td>
</tr>
<tr>
<td>Manis palaeojavanicus</td>
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</table>
Contemporary Disappearance

<table>
<thead>
<tr>
<th>Sarawak*</th>
<th>Malaysia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carnivora/Felidae</td>
<td>Carnivora/Felidae</td>
</tr>
<tr>
<td>Tapirus indicus</td>
<td>Dicerorhinus sumatrensis</td>
</tr>
<tr>
<td>Dicerorhinus sumatrensis</td>
<td>Rhinoceros sondaicus</td>
</tr>
<tr>
<td>Bos gaurus</td>
<td>Elephas maximus</td>
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<tr>
<td>Bos javanicus</td>
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<tr>
<td>Primates</td>
<td></td>
</tr>
<tr>
<td>Flying fox</td>
<td>Flying fox</td>
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<tr>
<td>Pheasant &amp; Hornbill</td>
<td>Pheasant</td>
</tr>
</tbody>
</table>

*58 spp hunted & eaten (Abdullah et al. 2010)
A = localised

Knowledge Gaps in Sarawak

1. Incomplete knowledge on biodiversity: Ecosystem, Taxonomic, Cultural (e.g. frog & microbats vocalisation) & Genetic diversity
2. Protected areas (PA) & land use (LU): define PAs, TPAs, assumptions, methods; Is 10% PAs enough?
3. PAs & species diversity not fully understood
4. Interconnected PA network for better management? ESU vs MU; Single vs metapopulations.
5. Specific biodiversity priorities? Rare vs charismatic
6. Long term impact of climate change on faunal and floral assemblages not fully understood.
Gap on Climate Change, Ecology & EID Links

Climate change

- Rainfall
- Temperature
- Season & phenology

Emerging Infectious Diseases (EID)

Ecological Diversity - natural & disturbed habitats

Wildlife Dispersal and Population Dynamics

- Potentially zoonotic microbes & pathways - fungi, protozoa, bacteria & virus

Is Logjam Affecting Marine Biology?

1. Deforestation; increase GHGs >> climate change
2. Loss of faunal and floral assemblages
3. Increase surface runoff, erosion, landslides, logjam
4. Polluted river & lake systems; sedimentation
5. Upsetting mangrove, estuarine & mudflat ecology
6. Loss of fishery nurseries & migratory bird stopover
7. Affecting marine biology >> economic loss
Example: Strategic Framework & Actions

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Strengthen and integrate climate change, biodiversity, agriculture, fishery, energy &amp; water agenda into Federal legal framework and governance.</td>
<td>Harmonize &amp; coalesce Federal and State regional laws and policies on climate change, biodiversity, energy and waterbodies</td>
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<tr>
<td></td>
<td>JPM &gt; Science Advisor &gt; Akademi Sains Negara &gt; Coordinating Agency</td>
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<tr>
<td></td>
<td>Integrate climate change, biodiversity, energy &amp; water resources into sectoral planning</td>
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<td>Enhance research and training skills using state of the art technologies and predictive modeling.</td>
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<td></td>
<td>Enhance institutional capabilities and competence</td>
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<td></td>
<td>Centre of Excellence in Biological Diversity &amp; Climate Change in Sarawak</td>
</tr>
</tbody>
</table>
### Strategy 2

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Creative, sustainable &amp; guaranteed funding mechanism; <strong>less addiction</strong> on the government grant handouts.</td>
<td><strong>A new species name for a million; YTL, Ananda, Bukhari, Kouk, Genting, etc, etc.</strong></td>
</tr>
<tr>
<td></td>
<td>5-10% green tax on private large-scaled agricultural plantations &amp; timber extraction</td>
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<tr>
<td></td>
<td>5-10% tax on extractive natural resources projects</td>
</tr>
<tr>
<td></td>
<td>5-10% f the Federal budget.</td>
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<td></td>
<td>Ecological compensation for water and wetland-based alienation projects</td>
</tr>
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<td></td>
<td>1% ecological compensation on fossil fuel use</td>
</tr>
<tr>
<td></td>
<td>Tax break for private research on green technology</td>
</tr>
<tr>
<td></td>
<td>Tax break on environmental and ecological project donations.</td>
</tr>
</tbody>
</table>

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### Strategy 3

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Promote conservation of resource to reduce carbon footprint</td>
<td>Manage, maintain and preserve renewable and non-renewable resources.</td>
</tr>
<tr>
<td></td>
<td>Systematic inventory on forest, wildlife, climate change water and energy use</td>
</tr>
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<td></td>
<td>National grid of research plots to be monitored by research institutions</td>
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<td></td>
<td>GHGs monitoring, modeling and prediction</td>
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<td></td>
<td>Green lung in all urban, settlement and schools</td>
</tr>
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<td></td>
<td>Institutional support, capacity building &amp; management</td>
</tr>
<tr>
<td></td>
<td>Promote socio-environmental projects</td>
</tr>
<tr>
<td></td>
<td>Maintain ecosystems to deliver goods and services for our livelihood.</td>
</tr>
<tr>
<td></td>
<td>Maintain of sensitive ecosystem; mountain, wetlands and caves</td>
</tr>
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<td></td>
<td>Promote awareness</td>
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<tr>
<td>Strategy</td>
<td>Action</td>
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<tr>
<td>4. Restoration of ecosystem, population and species.</td>
<td>Established irrevocably TPAs and forest reserves</td>
</tr>
<tr>
<td></td>
<td>Reforestation and afforestation &gt;&gt; carbon sequestration.</td>
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<td></td>
<td>Sustainable forest management practices</td>
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<tr>
<td></td>
<td>Restocking &amp; restoration of endangered or depleted wildlife resources; Gene bank; cryopreservation</td>
</tr>
<tr>
<td></td>
<td>Habitat connectivity &gt;&gt; animal movement</td>
</tr>
<tr>
<td></td>
<td>Monitor and assess vulnerability</td>
</tr>
<tr>
<td></td>
<td>Promote awareness &amp; education</td>
</tr>
<tr>
<td>5. Sustainable utilisation</td>
<td>Use of wild stock or type for agriculture &amp; animal husbandry</td>
</tr>
<tr>
<td>6. Prevent Emerging Infectious Diseases</td>
<td>Predictive modelling based on ecological, hosts and climatic data.</td>
</tr>
</tbody>
</table>

**Acknowledgements**

- Majlis Profesor Negara, NRE & LESTARI UKM for giving us the opportunity to express our views.
- FRST & UNIMAS for supports; SFD/SFC & DWNP for research permits.
- Colleagues who provided constructive comments and Khairul Adha provided information on fish fauna.
References


Forearm length (FA), ear length (E), tibia length (TB), hind foot length (HF), tail to ventral length (TVL), second digit metacarpal length (D2MCL), third digit metacarpal length (D3MCL), third digit first phalanx length (D3P1L), third digit second phalanx length (D3P2L), fourth digit metacarpal length (D4MCL), fourth digit first phalanx length (D4P1L), fourth digit second phalanx length (D4P2L), fifth digit metacarpal length (D5MCL), fifth digit first phalanx length (D5P1L) and fifth digit second phalanx length (D5P2L).

Greatest skull length (GSL), interorbital width (IOW), postorbital width (POW), cranial width (CW), mastoid width (MW), zygomatic width (ZW), post palatal length (PPL), palatal length (PL), distance between cochlæae (OBC), bulla length (BL), greatest basal pit length (GBPPL), and dentary length (DL).

Canine tooth basal width (C1BW), breadth across both canine outside surfaces (C1C1B), breadth across both third molar teeth outside surfaces (M3M3B), canine molar length or maxillary tooth row length (C1M3L), second molar tooth crown length (M2L), and second molar tooth crown width (M2W).